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Hospitalization Resource Use and Costs Before and After TIA and Stroke: Results from a Population-Based Cohort Study (OXVASC)

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A B S T R A C T

Objectives: High hospitalization rates, prolonged length of stay, and increased risks of subsequent events mean a steep increase in health care usage after stroke. No study, however, has examined to what extent increased costs after transient ischemic attack (TIA) or stroke are due to hospitalizations for the initial event, recurrent events, and/or nonvascular hospitalizations, and how costs compare with the year prior to the event. **Methods:** We studied patients in a population-based cohort study (Oxford Vascular Study) in the United Kingdom from 2003 to 2007. Hospitalization and cost details were obtained from patients' individualized Hospital Episode Statistics records. **Results:** A total of 295 incident TIA and 439 incident stroke patients were included. For patients with stroke, average costs increased from £1437 in the year pre-event to £6629 in the year post-event ($P < 0.0001$). Sixty-four percent (£4224) of poststroke costs were due to hospitalizations linked to the index stroke, more than 30% of which were given nonvascular primary diagnoses on Hospital Episode Statistics, and £653 (10%) were due to hospitalizations linked to subsequent vascular events. For patients with TIA, costs increased from £876 1 year before the event to £2410 in the year post-event ($P < 0.0001$). Patients with TIA incurred nonsignificantly higher costs due to hospitalizations linked to subsequent vascular events (£774) than for hospitalizations linked to the index TIA (£720). **Conclusions:** Hospital costs increased after TIA or stroke, primarily because of increased initial cerebrovascular hospitalizations. The finding that costs due to nonvascular diagnoses also increased after TIA or stroke appears, in part, to be explained by the miscoding of TIA/stroke-related hospitalizations in electronic information systems.

Keywords: cost analysis, health care utilization, regression modeling, stroke.

Introduction

High hospitalization rates, prolonged length of stay and rehabilitation, and an increased risk of subsequent vascular events mean a steep increase in the use of health care resources and costs after stroke and to a lesser extent after transient ischemic attack (TIA) [1–4]. In addition, there is evidence that patients with stroke are at an increased risk of infection [5], falling [6], and experiencing bone fractures [7], with a further increased likelihood of higher hospital use and costs.

As TIA and stroke are associated with old age and generally occur in patients with other comorbidities [8], such patients are likely to consume substantial hospital resources even if they had not suffered a TIA or stroke, making the impact of disease on costs difficult to determine. Despite this, evidence from a literature review showed that only a minority of studies assessed the costs that could be directly attributed to TIA or stroke by either comparing costs of patients with controls or comparing costs incurred before the event to subsequent costs [9], with none including patients with TIA [9]. In addition, no study examined the reasons for the observed increase in costs after stroke, that is, whether observed increases in costs were due to hospitalizations for the initial event, recurrent events, and/or noncerebrovascular causes.

The objective of this study, therefore, was to compare differences in hospitalization resource use and costs during the 12 months before and after TIA or stroke onset and to investigate the reasons for any observed differences between the two time periods.

Methods

The Oxford Vascular Study

The Oxford Vascular Study (OXVASC) population comprises more than 91,000 patients registered in nine general practices across Oxfordshire, UK. The study methods have been described elsewhere [8]. Briefly, patient registration began on April 2002 and is ongoing. Only consenting patients recruited from April 1, 2003, to March 31, 2007, were included in this analysis. Patients recruited between April 1, 2002, and March 31, 2003, were excluded as electronic Hospital Episode Statistics (HES) records for the year before the event were not obtained. Patients in whom TIA or

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stroke was suspected were ascertained by using multiple overlapping methods of "hot" and "cold" pursuit and considered for inclusion [10], including the following:

1) A daily (weekdays only), urgent open-access "TIA clinic" to which participating general practitioners and the local accident and emergency department send all individuals with suspected TIA or stroke whom they would not normally admit to hospital, with alternative on-call review provision at weekends;
2) Daily searches of admissions to the medical, stroke, neurology, and other relevant wards;
3) Daily searches of the local accident and emergency department attendance register;
4) Monthly computerized searches of general practitioner diagnostic coding and hospital discharge codes;
5) Monthly searches of all cranial and carotid imaging studies performed in local hospitals; and
6) Monthly reviews of all death certificates and coroners reports.

Patients with suspected TIA/stroke were assessed urgently by a study clinician. Stroke was defined according to World Health Organization definitions and included all ischemic events, intracerebral hemorrhage, subarachnoid hemorrhage, and strokes of uncertain type. Informed consent was sought, and assessments of neurological impairment, history of presentation, medical and social history, and risk factors were performed. Impairment was measured by using the National Institutes of Health Stroke Scale (NIHSS), which was used to categorize event severity. Minor events were defined as NIHSS scores of less than or equal to 3, moderate as scores from 4 to 10, and severe as scores of more than 10.

To better understand the impact of stroke and TIA on hospital resource use and costs, we excluded from the analyses all those patients with a history of stroke and TIA. Surviving patients were then followed-up face to face by a research nurse at 1, 6, 12, 24, and 60 months after the event. Patients were also followed-up via their general practitioner records, recurrent vascular events were identified by ongoing ascertainment, and all patients had mortality follow-up.

Resource use

Resource use for each patient was obtained from the date of first TIA or stroke within the OXVASC period (i.e., index event) until 1-year follow-up or death within that period. In addition, the resources consumed within the 12 months prior to the index event were obtained. Details of hospital admissions were obtained from the patient's HES records [11]. HES contain details of all admissions to English hospitals funded by the National Health Service (NHS). For each hospital admission, HES provided information on the primary diagnosis and secondary diagnoses (coded using *The International Statistical Classification of Diseases and Related Health Problems, 10th Revision* [*ICD-10*]), date of admission and discharge, admission method, and details about the procedures and operations undertaken during each admission (coded by using the Tabular List of the Classification of Surgical Operations and Procedures).

For hospitalizations in which the patient was admitted and discharged on the same day, the number of days in hospital was 0 and the hospitalization was classified as a day case. When the index event occurred while in hospital, the hospital days before the event and those on or after the event were treated as pre- and postevent days, respectively. For those hospitalizations in which the patient was admitted during the 1-year study period after the index event, but discharged more than 1 year after event onset, we took into account only the days in hospital occurring during the 1-year period.

Reasons for hospitalization were determined by examining the primary diagnosis codes. For the purpose of our analysis, cerebrovascular hospitalizations were those with an *ICD-10* primary diagnosis code of G450 to G648, H340 to H342, H348, or I600 to I698; cardiovascular were those with *ICD-10* codes of I00 to I528, or I700 to I99; and those hospitalizations with any other *ICD-10* primary diagnosis code were recorded as nonvascular. As hospitalizations could have more than one primary diagnosis (e.g., an admission diagnosis and a discharge diagnosis), hospitalizations with multiple primary diagnoses in which at least one was for cerebrovascular disease were coded as cerebrovascular, irrespective of other primary diagnoses.

Hospitalizations occurring within 7 days of the index event (including those in which the index event occurred while in hospital), irrespective of primary diagnosis, were linked to that event. In addition, if the patient was subsequently discharged to another hospital, that hospitalization was also linked to the event (e.g., patient was transferred from the acute hospital to a community hospital). By using the same methodology, we also linked hospitalization information with subsequent vascular events, including stroke, TIA, and coronary and peripheral vascular disease events. Subsequent vascular events were identified by face-to-face follow-up and as part of the ongoing OXVASC ascertainment process. However, for those patients already hospitalized when a subsequent vascular event occurred, it was not possible to separately attribute resources to the multiple events and so all the days in hospital were combined together as part of the initial event.

Unit costs

In England, NHS hospitals are reimbursed for the services they provide through a national tariff of prices reflecting the national average cost of providing a hospital service. Each hospital service is assigned to a Health Resource Group (HRG) that groups together similar clinical procedures that cost an equivalent amount to deliver [12]. Prices in the national tariff have been set on the basis of the average cost of providing a particular HRG by using data gathered from NHS hospitals. In addition, hospitals receive additional funding for high-cost drugs, additional hospitalization days past a certain threshold, and provision of direct-access diagnostics and specialized rehabilitation.

Each hospitalization was valued by using the 2008/09 HRG English tariff. To determine the HRG for each hospitalization, and any additional payments received for the provision of additional services, each hospitalization in HES was coded by using the HRG grouper (version 4 2008/09) software (The Health and Social Care Information Centre, Leeds, UK). HRGs were then linked to a series of elective and emergency reference costs obtained from the 2008/09 schedule of NHS reference costs [13].

Statistical analyses

Hospitalizations were reported as rates (i.e., the total number of hospitalizations divided by the total time of observation). Rates before and after the event were reported with their standard error and compared by using rate ratios reported alongside 95% confidence intervals (CIs). Statistical differences were evaluated assuming a Poisson distribution. Days in hospital and costs were reported as means together with their SD, with mean differences between the two time periods reported alongside 95% CIs, and evaluated by using a Student's two-sided t test. Hospital days and costs for patients dying after the index event were analyzed in the same way as for survivors.

To assess the predictors of costs during the year after the index event, a two-part regression model was used. A logistic regression was first used to assess the predictors of having at least one hospital admission during the year following the index event. Conditional on having at least one admission, a log-linear regression, using robust standard errors, was used to determine the predictors of 1-year total costs after the index event. Potential predictors included sex; age; previous history of myocardial infarction, angina, peripheral vascular disease, hypertension, atrial fibrillation, diabetes, and disability; premorbid socioeconomic characteristics including age at which patient left education, marital status, place of residence, deprivation—as measured by post code of residence using the index of multiple deprivation, social class—as coded using the Standard Occupational Classification Scheme, and employment status; event type; and event severity (NIHSS score). Because of observed nonlinear effects on resource use and costs [14], event severity was included in the model by using the continuous NIHSS score and its quadratic term. Age was included as a categorical variable.

Statistical significance was set at $P < 0.05$. In both multivariate analyses, model specification was tested by using Ramsey's reset test and multicollinearity in the predictor variables was measured from the tolerance value and its inverse, the variance inflation factor (VIF). The tolerance value is the amount of variability of a single predictor variable not explained by other predictor variables, whereas VIF indicates the extent of effects of other predictor variables on the variance of a selected predictor variable. Very small tolerance values (<0.1) or high VIF values (>10) indicated high collinearity [15]. For the log-linear regression, we tested normality of residuals by using Kolmogorov-Smirnov's χ^2 test and by plotting residuals alongside a normal empirical distribution. To assess the performance of the logistic regression model in predicting hospitalization after the index event, we estimated the *c* statistic, which assesses how the model correctly predicts a higher probability of hospitalization in those patients who were hospitalized than the probability for patients who were not hospitalized. The *c* statistic was computed from the area under the receiving operating characteristic curve.

Table 1 – Baseline and event characteristics for TIA and stroke patients.

	Stroke (n = 439)	TIA (n = 295)
Age (y), mean ± SD	74 ± 13	71 ± 14
Males	225 (51)	126 (43)
Previous disability	82 (19)	32 (11)
Previous MI*	46 (11)	23 (8)
Previous angina*	57 (13)	34 (12)
Hypertension*	246 (57)	136 (46)
Diabetes*	38 (9)	41 (14)
NIHSS score,† median (IQR)	2 (0–6)	0
Minor stroke	261 (61)	
Moderate stroke	100 (23)	
Severe stroke	69 (16)	
Stroke type		
Ischemic stroke	354 (81)	
Primary intracerebral hemorrhage	39 (9)	
Subarachnoid hemorrhage	27 (6)	
Unknown stroke	19 (4)	
≥1 subsequent events		
TIA	10 (2)	57 (19)
Stroke	52 (12)	42 (14)
Coronary events	14 (3)	7 (2)
Peripheral vascular disease events	3 (1)	1 (<1)

Note. All data expressed as n (%), except where specified. IQR, interquartile range; MI, myocardial infarction; NIHSS, National Institutes of Health Stroke Scale; TIA, transient ischemic attack.
* Stroke: 6 missing; TIA: 2 missing.
† Stroke: 9 missing; TIA: 5 missing.

Results

Patient Sample

Between April 2003 and March 2007, 379 patients suffered a TIA and 568 patients suffered a stroke as their first cerebrovascular event during the OXVASC period. Of these, 84 (22%) patients with TIA and 129 (23%) patients with stroke were excluded from this analysis because of a previous history of TIA or stroke. As a result, 295 patients with TIA and 439 patients with stroke were included in the analysis.

Of the 439 patients suffering an index stroke, 109 (25%) died within 1 year following the index event. Eleven (4%) of the 295 patients with TIA died during the year following the index event. No patient was lost to follow-up during this time. Because of late presentation or event occurring out of area, there was missing NIHSS information for nine stroke cases. Of the 430 index strokes with available NIHSS scores, 261 (61%) were classified as minor, 100 (23%) as moderate, and 69 (16%) as severe. Patients with TIA and patients with stroke had considerable comorbidities at the time of their event, with 10% having a history of myocardial infarction and 50% suffering from hypertension (Table 1).

Of the 439 index strokes, 22 (5%) occurred while the patient was already in hospital and 8 (3%) of the 295 index TIA also occurred while the patient was in hospital.

Hospital Resource Use 1 Year Before and After Index TIA or Stroke

For patients with stroke, a total of 417 hospitalizations were observed over 439 patient years in the year before the stroke and a total of 720 hospitalizations were observed over 354 patient years in the year after the stroke. All-cause hospitalizations rose from 0.95 per patient per follow-up year before the event to 2.04 after the index event (rate ratio 2.14; 95% CI 1.86– 2.47; $P < 0.0001$; Table 2). This increase was observed because of significant increases in hospitalizations with cerebrovascular disease diagnoses (rate ratio 33.6; 95% CI 19.6–65.7) and nonvascular diagnoses (rate ratio 1.20; 95% CI 1.03–1.39). The average number of all-cause days in hospital also increased significantly (32 in the year after the event vs. 4 in the year before the event; $P < 0.0001$). For the purposes of this analysis, reasons for hospitalization were determined by using primary diagnosis codes. Supplementary details of the reasons for hospitalization, including secondary diagnoses, are reported in Appendix 1 in Supplemental Materials found at http://dx.doi.org/%2010.1016/j.jval.2012.10.013.

Of the 2.04 hospitalizations per patient per follow-up year occurring after the index stroke, 58% (rate 1.19) were linked to the index stroke and 8% (rate 0.18) were linked to subsequent vascular events (Table 3). Most (64%) of the hospitalizations linked to the index stroke (rate 0.76) and 56% (rate 0.10) of the hospitalizations linked to subsequent vascular events were coded by using a cerebrovascular disease diagnosis, but a considerable minority of hospitalizations linked to the index or subsequent events were coded by using nonvascular disease diagnoses.

For patients with TIA, a total of 118 hospitalizations were observed over 295 patient years in the year before the event and a total of 294 hospitalizations were observed over 289 patient years in the year after the event. Patients with TIA also had significantly higher hospitalization rates in the year after the index event than in the year before it (1.02 vs. 0.40 per patient per follow-up year, respectively; $P < 0.0001$), and spent, on average,

Table 2 – Hospitalizations, days in hospital, and hospitalization costs 1 y before and after index TIA or stroke by *ICD-10* diagnosis.

	Stroke (n = 439)			TIA (n = 295)		
	Before	After	Rate ratio/mean difference (95% CI)	Before	After	Rate ratio/mean difference (95% CI)
Number of hospitalizations per patient per follow-up year (rate, SE)						
All causes	0.95 (0.05)	2.04 (0.08)	2.14 (1.86 to 2.47)	0.40 (0.04)	1.02 (0.06)	2.54 (2.05 to 3.18)
Cerebrovascular	0.03 (0.01)	0.92 (0.05)	33.6 (19.0 to 65.7)	0	0.26 (0.03)	NA
Cardiovascular	0.10 (0.02)	0.13 (0.02)	1.33 (0.86 to 2.05)	0.07 (0.02)	0.11 (0.02)	1.63 (0.91 to 3.01)
Nonvascular	0.82 (0.04)	0.98 (0.05)	1.20 (1.03 to 1.39)	0.33 (0.03)	0.65 (0.05)	1.95 (1.52 to 2.51)
Mean ± SD number of days in hospital						
All causes	4 ± 13	32 ± 53	28 (23 to 33)	2 ± 13	8 ± 25	6 (3 to 9)
Median (IQR)	0 (0)	6 (0 to 41)		0 (0)	0 (0 to 2)	
Cerebrovascular	<1 ± 3	20 ± 42	20 (16 to 23)	0 ± 0	3 ± 15	3 (1 to 5)
Cardiovascular	1 ± 4	2 ± 10	1 (−1 to 2)	<1 ± 1	1 ± 8	1 (0 to 2)
Nonvascular	3 ± 12	11 ± 29	8 (5 to 11)	2 ± 13	4 ± 15	2 (−1 to 4)
Mean ± SD hospitalization costs (£)						
All causes	1,437 ± 4,226	6,629 ± 11,503	5,192 (4,124 to 6,260)	876 ± 3,553	2,410 ± 5,587	1,534 (920 to 2,148)
Median (IQR)	0 (0 to 617)	2,772 (378 to 7,205)		0 (0)	0 (0–2,180)	
Cerebrovascular	65 ± 548	3,543 ± 7,636	3,478 (2,767 to 4,189)	0 ± 0	802 ± 2,821	802 (479 to 1,125)
Cardiovascular	331 ± 1,802	455 ± 2,928	124 (−188 to 437)	82 ± 651	293 ± 1,873	211 (−12 to 433)
Nonvascular	1,041 ± 3,710	2,631 ± 8,125	1,590 (898 to 2,280)	794 ± 3,503	1,315 ± 3,935	521 (68 to 975)

CI, confidence interval; *ICD-10*, *The International Statistical Classification of Diseases and Related Health Problems, 10th Revision;* IQR, interquartile range; NA, not available; TIA, transient ischemic attack.

8 days in hospital in the year post-event compared with 2 days pre-event (mean difference 6 days; 95% CI 3–9; $P < 0.0001$). When comparing days in hospital in the year before and after the index TIA, significant increases in hospital bed days were observed for cerebrovascular ($P = 0.0001$) and cardiovascular diagnoses ($P = 0.045$) but not for nonvascular diagnoses ($P = 0.087$; Table 2).

Of the 1.02 hospitalizations per patient per follow-up year occurring after the index TIA, 25% (rate 0.26) were linked to the index TIA and 17% (rate 0.17) to subsequent vascular events (Table 3). A total of 54% (rate 0.14) of the hospitalizations related to the index TIA and 59% (rate 0.10) of those linked to subsequent vascular events were coded by using cerebrovascular disease diagnoses.

Hospital Costs 1 Year Before and After Index TIA or Stroke

For stroke patients, average hospitalization costs increased from £1437 1 year before the event to £6629 in the year post-event, representing a significant increase of £5192 (95% CI 4124–6260; $P < 0.0001$; Table 2). These cost increases were primarily due to increased costs in hospitalizations with a cerebrovascular disease diagnosis, which accounted for 67% (£3478; 95% CI 2767–4189) of the increase. Significant increases in costs were also observed for nonvascular hospitalizations (mean difference £1590; 95% CI 898–2,280; $P < 0.0001$). Of the £6629 costs incurred in the year after the index stroke, £4224 (64%) were due to hospitalizations linked to the index stroke and £653 (10%) due to subsequent vascular events (Table 3). Costs 1 year before and after index stroke, stratified by stroke type, are reported in Appendix 2 in Supplemental Materials found at http://dx.doi.org/%2010.1016/j.jval.2012.10.013.

For patients with TIA, total average costs increased from £876 1 year before the event to £2410 1 year after the index TIA, a significant increase of £1534 (95% CI 920–2148; $P < 0.0001$; Table 2). Fifty-two percent of this observed increase in costs was due to increases in cerebrovascular hospitalization costs, which significantly increased by £802 (95% CI 479– 1125; $P < 0.0001$) per patient after index TIA. In addition, nonvascular hospitalization costs (mean difference £521; 95% CI 68–975; $P = 0.025$) increased after the index TIA. Patients with TIA incurred nonsignificantly higher costs because of hospitalizations linked to subsequent vascular events (£720) than for hospitalizations linked to the index TIA (£774; $P = 0.846$; Table 3).

Predictors of 1-Year Costs After Index TIA or Stroke: Covariate Adjustment

A total of 108 (25%) patients with stroke and 163 (55%) patients with TIA did not have any hospitalization after the index event, and therefore incurred no hospitalization costs. To deal with this distribution of costs, we performed a two-part model to assess the independent predictors of 1) the patient being hospitalized at least once (i.e., incurring costs) and 2) conditional on having been hospitalized, the level of costs incurred.

The independent predictors of whether the patient would have at least one hospital admission after index TIA or stroke included previous history of peripheral vascular disease ($P = 0.018$); hospitalization in the year before the index event ($P = 0.005$); and event severity, where a nonlinear association was observed (Table 4). Increased NIHSS scores were predictive of being hospitalized at least once following the index event ($P < 0.0001$). However, very high NIHSS scores (reflected in the analysis by the quadratic term) were associated with a lower probability of being hospitalized ($P = 0.003$), because of very high case fatality and patients dying before reaching hospital. Socioeconomic class was also found to be predictive of subsequent hospitalization in the year following index stroke or TIA, with skilled nonmanual ($P = 0.039$) and partly skilled ($P = 0.021$) patients less likely to be hospitalized than those classed as skilled manual.

Conditional on hospital admission, stroke severity as measured by using the NIHSS score was an independent predictor of costs. The association between event severity and costs, however, was nonlinear, due to the greatly increased case fatality, and corresponding reductions in length of stay, observed at high NIHSS scores (Table 4). Those patients who incurred higher

Table 3 – Hospitalizations, days in hospital, and hospitalization costs due to index and subsequent events by *ICD-10* diagnosis.

	Hospitalizations per patient per year (SE)	Mean ± SD days in hospital	Mean ± SD hospitalization costs (£)
Stroke patients (n = 439)			
Within 7 d of index stroke*			
Any coding	1.19 (0.06)	23 ± 44	4,224 ± 9,405
Hospitalizations coded as cerebrovascular	0.76 (0.05)	17 ± 39	3,036 ± 7,151
Hospitalizations coded as cardiovascular	0.06 (0.01)	1 ± 5	185 ± 1,317
Hospitalizations coded as nonvascular	0.37 (0.03)	5 ± 19	1,002 ± 5,901
Within 7 d of subsequent vascular events*			
Any coding	0.18 (0.02)	2 ±16)	653 ± 4,126
Hospitalizations coded as cerebrovascular	0.10 (0.02)	1 ± 9	308 ± 1,993
Hospitalizations coded as cardiovascular	0.04 (0.01)	1 ± 8	187 ± 2,506
Hospitalizations coded as nonvascular	0.04 (0.01)	1 ± 8	158 ± 2,259
TIA patients (n = 295)			
Within 7 d of index TIA*			
Any coding	0.26 (0.03)	3 ± 16	774 ± 3,525
Hospitalizations coded as cerebrovascular	0.14 (0.02)	1 ± 11	329 ± 1,938
Hospitalizations coded as cardiovascular	0.02 (0.01)	<1 ± 4	95 ± 1,022
Hospitalizations coded as nonvascular	0.09 (0.02)	1 ± 11	350 ± 2,797
Within 7 d of subsequent vascular events*			
Any coding	0.17 (0.02)	2 ± 16	720 ± 3,252
Hospitalizations coded as cerebrovascular	0.10 (0.02)	1 ± 9	430 ± 1,968
Hospitalizations coded as cardiovascular	0.02 (0.01)	<1 ± 2	53 ± 588
Hospitalizations coded as nonvascular	0.05 (0.01)	1 ± 8	236 ± 1,751

ICD-10, *The International Statistical Classification of Diseases and Related Health Problems, 10th Revision*; SE, standard error; TIA, transient ischemic attack.

* Including associated hospital transfers.

hospitalization costs before the event incurred significantly higher costs post-event ($P = 0.001$). Patients with a history of atrial fibrillation before index stroke or TIA were also found to incur significantly higher costs post-event ($P = 0.036$).

For both regression models, we found that no predictor variable had a tolerance level below 0.1 and no VIF value higher than 10, which indicated no problems with collinearity.

Discussion

In line with other costing studies evaluating costs before and after stroke [1–4], our results showed increased hospitalization rates, days in hospital, and total costs after stroke. Despite the high costs observed during the first 12 months after the index stroke (£6629 on average), the costs incurred by these patients over the 1 year before their event were also considerable (£1437 on average). Our study, however, is the first to show that both hospital resource use and costs, as with stroke, increased considerably after TIA, from £876 in the year before TIA onset to £2410 in the year after.

Our study also improved on previous work by analyzing reasons for hospital use and costs. More than 67% of the increased levels of hospitalization costs observed in the year after the index stroke were due to significant increases in hospitalizations with a cerebrovascular event diagnosis. Such increases were primarily due to hospitalizations linked to the index stroke, with only a small minority of hospitalizations linked to subsequent vascular events. For TIA, most of the hospitalizations occurring in the year after index TIA were due to nonvascular causes, with only 25% of the hospitalizations occurring within 7 days of the index TIA and a further 17% due to subsequent vascular events.

Our study showed that for patients with TIA and patients with stroke, when compared with the 12 months before the index event, costs for hospitalizations with nonvascular diagnoses increased significantly after event onset (from £1041 to £2631 in patients with stroke and from £794 to £1315 in patients with TIA). For patients with stroke, the increased costs were driven mainly

Table 4 – Independent predictors of 1-y hospitalization and costs after TIA and stroke.

	Hospital admission after event		If hospitalized, 1-y costs (log transformed)	
	Odds ratio	$P > \lvert z \rvert$	Coefficient	$P > \lvert z \rvert$
Hospitalized before event	1.47	0.005	NA	NA
Costs before event	NA	NA	<0.01	0.001
Gender				
Female	Reference case		Reference case	
Male	1.23	0.361	−0.15	0.222
Age (y)				
<65	0.76	0.444	−0.18	0.379
65–74	0.65	0.105	−0.34	0.038
≥75	Reference case		Reference case	
Previous history of				
Peripheral vascular disease	3.28	0.018	0.32	0.126
Myocardial infarction	1.05	0.904	<0.01	0.991
Angina	1.05	0.894	−0.45	0.014
Hypertension	1.05	0.797	−0.05	0.691
Atrial fibrillation	1.32	0.361	0.30	0.036
Disability	1.55	0.242	0.09	0.563
Event type				
TIA	Reference case		Reference case	
Stroke	1.51	0.068	0.24	0.102
NIHSS score	1.50	<0.001	0.11	0.001
NIHSS score ^ 2	0.99	0.003	−0.01	0.037
Premorbid place of residence				
Own home	Reference case		Reference case	
Home friend/family	0.66	0.621	−0.46	0.395
Warden accommodation	3.03	0.110	0.27	0.313
Care home	0.66	0.625	−0.69	0.067
Lived alone before event	1.00	0.989	−0.08	0.715
Premorbid marital status				
Married	Reference case		Reference case	
Widowed	1.18	0.655	0.13	0.593
Single	0.65	0.355	0.44	0.105
Separated	1.28	0.588	−0.18	0.552
Living with partner	0.81	0.747	0.19	0.504
Premorbid employment status				
Full-time	1.05	0.897	−0.18	0.483
Part-time	1.23	0.570	0.31	0.226
Caring for home	1.32	0.667	0.53	0.139
Unemployed	0.68	0.667	0.32	0.381
Unable to work	3.99	0.120	−0.20	0.612
Retired	Reference case		Reference case	
Socioeconomic status				
Professional	0.62	0.269	0.01	0.967
Managerial	0.83	0.537	0.09	0.577
Skilled nonmanual	0.51	0.039	−0.24	0.239
Skilled manual	Reference case		Reference case	
Partly skilled	0.44	0.021	0.24	0.282
Nonskilled	0.88	0.741	0.13	0.502
Age left education	0.97	0.397	−0.03	0.103
Index of multiple deprivation	1.01	0.378	−0.01	0.681
Constant	0.99	0.992	8.61	<0.001
	No.	633	No.	405
	$P > \chi^2$	<0.001	$P > F$	<0.001
	Adjusted R^2	0.126	Adjusted R^2	0.175
	c Statistic	0.790	RMSE	1.102
			Reset test	0.311
	Reset test	0.367	Kolmogorov-Smirnov	0.579

NA, not applicable; NIHSS, National Institutes of Health Stroke Scale; TIA, transient ischemic attack.

by significant increases in hospitalizations with *ICD-10* Chapter 11 (Diseases of the Digestive System), Chapter 14 (Diseases of the Genitourinary System), and Chapter 18 (Symptoms, Signs and Abnormal Clinical Findings) diagnoses, whereas for patients with TIA, the increases were driven mainly by rises in hospitalizations with Chapter 10 (Diseases of the Respiratory System), Chapter 18 (Symptoms, Signs and Abnormal Clinical Findings), and Chapter 21 (External Causes of Morbidity and Mortality) diagnoses.

Previous studies have shown that hospital coding is subject to error [16–18]. We found that 31% of the hospitalizations linked to the index stroke were not given a primary diagnosis of cerebrovascular disease (with only 11% of these hospitalizations having a secondary diagnosis of cerebrovascular disease). While a number of these may genuinely have been entirely unrelated, it seems highly likely that most use was in fact related to the index event. Therefore, our findings that nonvascular hospitalization resource use and costs increased after the index event could be partly explained by TIA and stroke not being coded appropriately in HES records. The findings from our study, therefore, caution against including only those costs directly associated or attributable to a disease or intervention in a costing study or an economic evaluation. In our case, if only those hospitalizations with a primary diagnosis of cerebrovascular disease were to have been considered in this study, the impact of TIA or stroke on subsequent costs would have been severely underestimated.

Our study was based on an unselected patient sample, including all relevant patients regardless of whether they were initially treated in the community or in hospital. We believe that our cost results will provide useful information to help plan service provision and resource allocation. Our cost results will also be of use to other researchers as an input to decision-analytic models, which are becoming increasingly popular to assess the cost-effectiveness of specific intervention to prevent or treat stroke. Our overall costs are, of course, applicable only to the United Kingdom and possibly to similar health care systems in which a high proportion of patients with minor stroke and TIA are investigated and treated in the outpatient setting. However, our predictors of cost are more likely to be generalizable to other health care settings.

However, our study had a number of limitations. First, although HES records also contain information on outpatient and emergency care contacts, such information does not include any diagnosis. We also did not include resource use and costs associated with primary care and social care (including long-term institutionalization into a care home), the latter accounting for a high proportion of post-stroke costs [9]. As better primary and outpatient care have been shown to reduce the risk of both incident and recurrent stroke [19,20], data on these costs might have revealed associations between primary/outpatient care and inpatient care costs. Second, we did not include 267 patients recruited during the first year of OXVASC as we did not obtain HES records for the year before their index event. This reduced the study sample and the power required to perform statistical analyses.

As stroke and TIA are associated with old age and often occur in patients with other comorbidities [8], such patients are therefore likely to consume substantial health care resources even if they had not had a cerebrovascular event. In this study, we assessed the costs that could be directly attributable to stroke and TIA by comparing costs 1 year before and after the index event. As with any before and after study, there is the possibility that unobserved external factors could have biased our results. Another way to assess the costs that could be directly attributable to stroke or TIA, and limit the potential for such bias, would have been a case-control study in which the costs incurred by patients with stroke or TIA were compared with those incurred by gender- and age-matched controls. Fourth, the low hospitalization rates following subsequent vascular events after index TIA or stroke were in part observed because the patient was already hospitalized because of the index event. So, for example, 46% of subsequent strokes occurred while the patient was already hospitalized for the index event. As it was not possible to separately attribute resources to the multiple events, all resource use and costs were combined together as part of the initial event. Finally, as HRG costs are particularly susceptible to primary diagnosis codes, a wrong primary diagnosis code would alter the cost attached to a particular hospitalization.

In conclusion, hospital costs increased considerably after index stroke or TIA, primarily because of increased cerebrovascular hospitalizations. The finding that hospitalizations and costs for nonvascular conditions also increased after the index event could in part be explained by the miscoding of TIA- or stroke-related hospitalizations in electronic information systems.

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Supplemental Materials

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